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ABSTRACT

This review of the literature on aptitude by treatment interaction concentrates on studies which investigated two or more instructional treatments in a quantitative subject area--primarily mathematics--with different populations of students on whom measures of individual differences in aptitude were available. Designed to formulate some tentative recommendations for matching instructional methods to individual differences between students, the review examines 61 studies investigating logical vs scrambled sequences in programmed instruction, linear vs branching programmed instruction, covert vs overt responding in programmed instruction, conventional instruction vs programmed instruction, deductive vs inductive sequencing, mastery vs convential instruction, verbal vs visual/spatial instruction, and conventional instruction vs new math. A brief summary of the results with recommendations is followed by six tables summarizing the major findings of the reports in each of the areas studied. (RAO)

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INDIVIDUALIZING INSTRUCTION IN QUANTITATIVE SUBJECT-MATTERS: CAPITALIZING ON APTITUDE BY TREATMENT INTERACTIONS[1]

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Introduction

In order to teach quantitative subjects, instruction probably should be individualized at least according to subgroups of students. The traditional way of doing this is to vary the rate with which individual students proceed through the instructional material. While students may master the material given sufficient time, this method may not be optimal or practical. Furthermore, it trades off achievement for time taken to achieve.

An alternative approach to individualizing instruction is to match different methods for teaching quantitative subjects to the aptitudes[1] of students. With this approach, an attempt is made to optimize students' knowledge and skills in quantitative subjects by matching methods by which they receive instruction to their aptitudes. This perspective assumes that there is more than one way to teach a topic in quantitative subject areas. Method A might be appropriate for certain students while Method B might be appropriate for other ones.

This latter approach is the focus of this review for several reasons. First, as stated at the outset, individualizing instruction seems to help solve the problems created by a classroom of students differing greatly in aptitude. Second, since most schools use

a semester system, individualizing the rate of instruction seems not to be practical at present. (This does not argue for status quo; it simply faces a present reality.) And third, adapting instructional methods to fit individual differences between students focuses attention on effective and efficient solutions to the problem of instructional design.

The purpose of this review is to set forth tentative recommendations for matching instructional methods in quantitative subjects to individual differences between students. To the practitioner, these recommendations represent "best bets" for individualizing instruction at this point in time. To researchers, these recommendations represent hypotheses to be tested empirically.

The method used to arrive at these recommendations is literature review. In reviewing the literature, a particular type of empirical study was sought. The study had to deal with a quantitative subject matter and had to include:

a) one or more measures of students' aptitudes (e.g., a pretest, a mathematical aptitude test, a personality test); and

b) two or more instructional methods for teaching the quantitative subject matter (e.g., inductive vs. deductive sequencing, programmed instruction vs. traditional instruction, new math vs. old math).

Of particular interest was a finding that instructional Method A led to higher posttest achievement than Method B (Method A > Method B)

for one kind of student, while, for a second kind of student just the reverse occurred (Method B > Method A) or no differences were found (Method A = Method B). In statistical terms, the review focused on results of empirical research in which an interaction was found between a measure of aptitude and a measure of an outcome in different treatments. As a pictorial example of the results sought by this review, an aptitude by treatment interaction (ATI) is shown in Figure 1. In the example, Method A is better than Method B for students low in aptitude while Method B is better than Method A for students high in aptitude. Results such as these lead to a decision rule for individualizing instruction by matching instructional methods to different groups of students:

a) If a student is low in aptitude, assign him/her to Method A;

b) If a student is high in aptitude, assign him/her to Method B;

c) Otherwise, assign to either A or B.

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Insert Figure 1 about here

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As another example, an ATI in which Method A is superior to Method B for low aptitude students but the two methods do not differ for high ability students is shown in Figure 2. Results such as these lead to the following decision rule:

a) If a student is low in aptitude, assign him/her to Method A;

b) Otherwise, assign to either Method A or Method B.

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Insert Figure 2 about here

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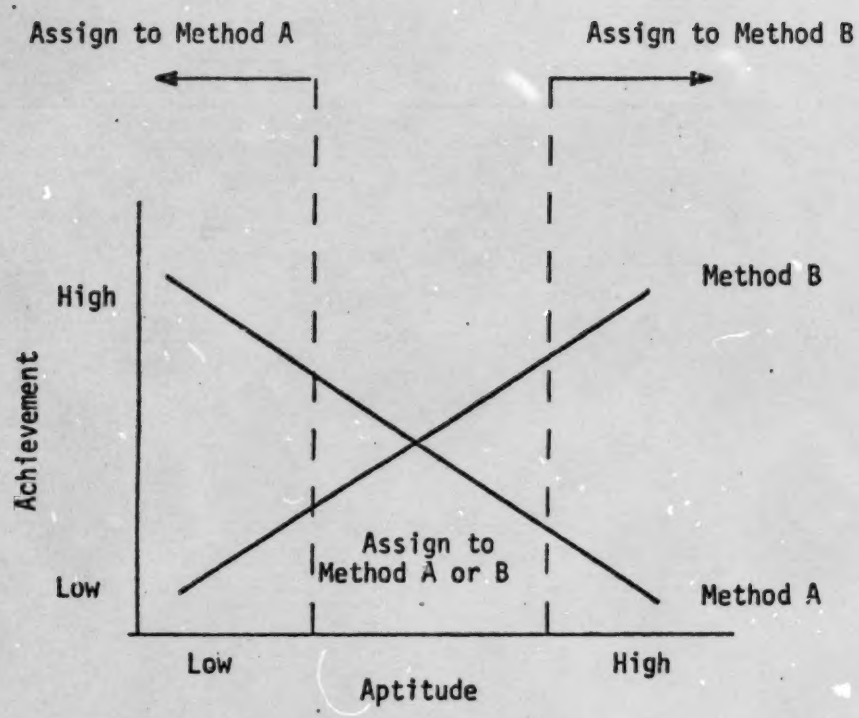

Figure 1. Regression of achievement on aptitude for each instructional method.

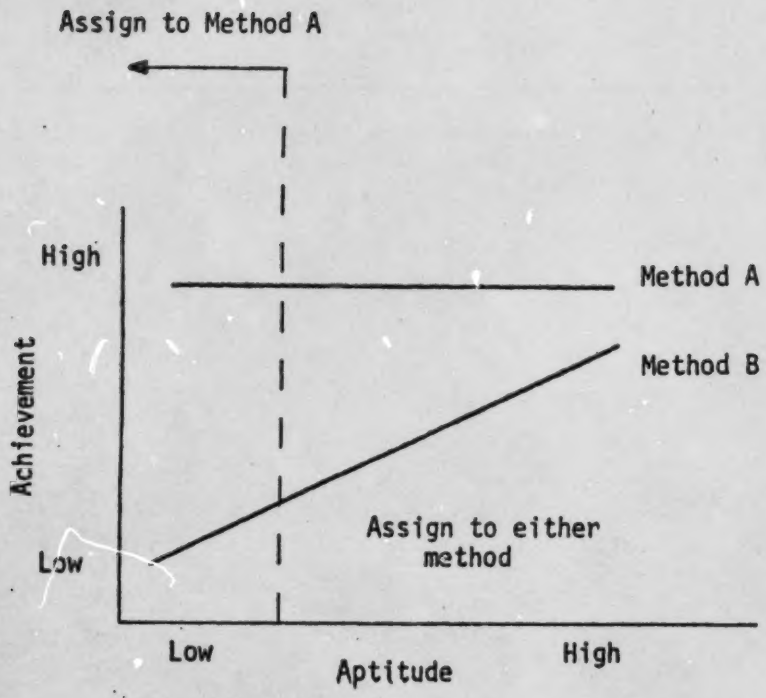

Figure 2. Regression of achievement on aptitude for each instructional method.

A plausible hypothesis for assigning students to different methods for teaching quantitative subjects, in the absence of specific studies in the area being taught, on a relevant student population, or both, is given by Tobias (1976; see also Tobias, 1978, Note 1).

> [T]he higher the level of prior achievement [e.g., pretest score], the lower the instructional support required to accomplish instructional objectives. Conversely, as level of prior achievement decreases, the amount of instructional support required increases (p. 67).

For Tobias, increasing instructional support includes organizing stimulus input (e.g., structuring and editing instructional material; excising irrelevant material, programming instruction) and increasing evaluative feedback (e.g., criterion-referenced tests, knowledge of results).

The results of this review lead to a slight revision of Tobias' hypothesis as follows: The higher the level of ability (pretest, achievement test, general mental ability), the lower the instructional support required to reach cognitive objectives in instruction with quantitative subject matters. Conversely, as the level of ability decreases, the amount of instructional support required increases. The revision is that this prescription includes general mental ability as well as pretests. This revision is based on Snow's work (Cronbach & Snow, 1977; Snow, 1976, Note 2) and the review that follows. For the studies reviewed in this paper, increasing instructional support means using, for example, deductive rather than inductive

sequencing in instruction, or algorithmic instead of conceptual instruction. As might be expected, there are exceptions to this rule which are reflected in the recommendations for matching students to instructional treatments. These recommendations and exceptions are presented in the final section of this review. The body of this review provides documentation for them.

Approach Taken in Reviewing the Literature

In reviewing literature, studies were initially sought with high school and college level populations of students receiving instruction in, for example, algebra, trionometry and statistics by two or more instructional methods. Needless to say, there was a paucity of such studies. So, the literature search was expanded in two ways. First, the search was not restricted to the aforementioned subject matters. Rather, it included all types of mathematics and other subject matters that were primarily quantitative in nature such as physics. Second, the search was not restricted to high school and college level populations. Rather, populations at any level of schooling were included in the search. This means that studies in this review included two or more instructional treatments in a quantitative subject matter with different populations from school age students on whom measures of individual differences in aptitude were available.

In searching the literature for ATI studies, Cronbach and

Snow's (1977) review of ATI research was used to identify relevant literature up to 1976. This compendium, which includes comprehensive reviews of ATI studies, is considered a classic; studies cited by Cronbach and Snow were reviewed here. Our critique and interpretation of studies were compared with Cronbach and Snow's for those reviewed in common. Additional studies were found in a search of the literature from 1973 to the present. A total of 61 studies, then, have been included in this reivew. While this number may not include all of the published ATI studies in quantitative subject matters, it probably includes most of them.

In order to organize the literature on ATI in quantitative subject matters, categories were defined for aptitudes and instructional methods. The aptitude variables were categorized into four groups, two of which have been suggested by Snow (1976, Note 2): (1) crystallized ability such as a pretest or mathematics achievement; (2) general mental ability (GMA) such as verbal ability or abstract reasoning; (3) spatial/visual ability such as a test of visualizing; and (4) personality traits such as measures of introversion-extroversion. As might be expected, the nature of the aptitude tests were not adequately described in the literature. As a consequence, some error in classification may have occurred.

The instructional methods were categorizied roughly into six groups representing pairs of instructional methods compared in the literature: (1) comparisons of methods and sequences of programmed instruction; (2) deductive vs. inductive instructional sequences;

(3) programmed vs. conventional instruction; (4) mastery vs. conventional instruction; (5) more verbal vs. less verbal instruction; and (6) old math vs. new math. In general, the first adjective of the adjective pair describing a comparison of treatments reflects more structure in instuction than does the second member of the pair. For example, a deductive sequence of instruction imposes more organization than does an inductive sequence.

A major problem with much of the literature is that instructional methods are inadequately defined. One researcher's "discovery" treatment might be another's "guided discovery" and still another's "didactic" method. This definitional problem made comparisons across studies quite difficult, especially when inconsistency in results arose. Nevertheless, if something is to be learned from previous research, the reviewer must do his or her best in order to make practical recommendations which are, in the final analysis, hypotheses.

In reporting the review of literature, studies are grouped first according to the instructional methods compared. Within the comparison of instructional methods, studies are grouped by the type of aptitude measured. In addition, care has been taken to identify subject matters (e.g., algebra, trigonometry, calculus, physics), the grade level of students, and the number of subjects in the study.

Results

Comparisons of Method and Sequences of Programmed Instruction

Studies comparing different methods and sequences of programmed instruction have been conducted with quantitative subject matters.

Most of the studies have compared smooth (logical) and scrambled (random) sequences of instruction stemming from research on programmed instruction. The logical sequence was comprised of a set of programmed-text frames organized according to small steps leading from the students' present capabilities to some instructional goal. The scrambled sequence was formed by randomly assigning frames in the sequence of programmed instruction. The scrambled sequence was often used as a comparison treatment to the logical sequence (until no differences or differences favoring the scrambled sequence were found; see Briggs, 1967). The studies falling into this group are summarized in Part I of Table 1.

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Insert Table 1 here

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A second manipulation of programmed instruction involves a comparison of linear programs (fixed sequences of frames) with branching programs (variable sequence based on errors). These studies are summarized in Part II of Table 1. Two other studies of programmed instruction examined ATIs by varing pacing (self vs. program). These are reported in Part III of Table 1. Finally, in programmed instruction (PI), students typcially are asked to respond to a question posed after every frame or set of frames. This response might be written so that the response is overt, or the response might be internally verbalized so that it is covert. Three studies which have examined ATI with overt vs. covert responding are summarized in

Part IV of Table 1.

A reasonably clear picture emerges from the studies summarized in Part I of Table 1. A scrambled sequence of programmed instruction seems to benefit students high in general mental ability (GMA) and not students low in GMA while logical instruction seems to benefit low ability students. Put in the form of a decision rule, assign low GMA students to the logical (organized) sequence--they seem to do almost as well as high ability students in this treatment--and assign high ability students to either treatment. This decision rule is not consistent with the findings of two studies in which students were grouped on crystallized ability (!). However, with only two studies and one showing great variability in the direction of the ATI, this finding is a curiosity, at best.

The evidence on linear vs. branched programs and on self-direction is equivocal. Either no differences were found or the data supported a tenuous interpretation that high ability students benefitted more from branching and self-direction than did low ability students.

The findings on overt and covert responding to PI suggest the following decision rule: Assign low ability students to a covert responding treatment and high ability students to an overt responding treatment.

Programmed vs. Conventional Instruction

Programmed instruction includes a wide range of instructional techniques which can be characterized generally as proceeding in small, logical steps with the student responding and being evaluated

("reinforced") at each step. PI may be mediated by a textbook, machine, auto-tutorial device, or computer. In the studies comparing PI with conventional instruction (CI), CI usually takes the form of textbook, lecture, or both. The studies falling into this category are summarizied in Table 2.

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Insert Table 2 here

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A consistent pattern of results for low and high ability students receiving CI and PI does not emerge. In some studies, CI (assumed to be less structured than PI) benefitted low ability students while, in other studies, CI benefitted high ability students. A major problem especially with these studies is that the differences in what constitutes CI and PI from one study to the next are quite large. In some cases, CI might be as structured or more so than PI (e.g., a student does not follow PI as intended). The work of Tobias (1976, 1978, Note 1) suggests that increasing the structure of instruction should benefit low ability students while decreasing structure should benefit high ability students when ability is defined as pretest scores or achievement test scores directly related to the content of instruction. The studies summarized under crystallized ability do not support this hypothesis.

Deductive vs. Inductive Sequence of Instruction

Studies comparing deductive and inductive sequences of instruction often have been motivated by the notion of discovery learning (e.g., Shulman & Keislar, 1966). A deductive sequence begins with the presentation of general rules or principles and systematically moves toward the application of those rules or principles to specific cases and examples. An inductive sequence (sometimes called discovery or guided discovery) begins with specific cases and examples and moves toward a generalization from the specific to general rules or principles. The studies falling into this group are summarized in Table 3.

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Insert Table 3 here

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The findings summarized in Table 3 support a conclusion that, for high ability students, inductive sequencing may lead to higher achievement than deductive sequencing. Even if it does not, high ability students seem to do no worse with inductive sequencing than with deductive sequencing. For low ability students, the structure provided by deductive sequencing may lead to higher achievement than inductive sequencing. Even if it does not, the main effect for deductive sequence found in three of the studies along with only one finding of greater benefit from inductive than deductive sequencing for low ability students (Brown, 1963) supports this conclusion. One final note in passing. While low ability students seem not to benefit as much from inductive as deductive sequencing as measured

by immediate achievement posttests, they may benefit from inductive sequencing when a measure of transfer is included (Branch, 1973, Note 3). But this is a hunch which needs detailed testing before a conclusion can be reached. Finally, with only one study involving a personality measure, a conclusion cannot be drawn.

Mastery vs. Conventional Instruction

The mastery model of instruction (Block, 1971; Bloom, Hastings & Madaus, 1971) is highly organized. Terminal objectives are specified, and a hierarchical sequence of instruction in the form of blocks of lessons is provided to take the student from his present capabilities ("entry behavior") to the terminal objectives. A student proceeds from one lesson to the next by demonstrating "mastery" of the previous lesson on an examination. Practice and corrective feedback are provided throughout the instruction. As usual, CI is a lecture, textbook, or both.

The results of these studies are summarized in Table 4. With only three interpretable studies, with inconsistent findings, recommendations for adapting instruction to treatments cannot be made.

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Insert Table 4 here

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Verbal vs. "Nonverbal" Instructional Modes

Instruction in quantitative subjects can vary the degree to which the material is presented in the form of words, and graphs and

pictures. Treatments relying on words and verbal symbols are labled verbal treatments while treatments emphasizing pictures and graphs are labled nonverbal although it should be clear that instruction cannot be totally nonverbal. The studies falling into this comparison of instructional methods are summarized in Table 5.

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Insert Table 5 here

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Again, a clear pattern in ATIs does not emerge. Indeed, the nature of the ATI may depend on the subject-matter. At best, verbal treatments do not seem to hinder students of varying abilities. In contrast, figural treatments tend to be beneficial for students scoring high on tests of figural ability (Behr, 1967; Young, 1973; Peterson & Hancock, 1974, Note 5), but the inconsistency of the Carry studies and the Kropp et al. (1967) study casts doubt on this.

The interpretation of theses findings is made even more difficult by the poor definitions and descriptions of treatments. For example, some researchers differentiate figural, verbal and symbolic treatments (e.g., Peterson & Hancock, 1974, Note 5) while others seem not to distinguish symbolic from verbal (e.g., Young, 1973). A cautious recommendation is the following: verbal treatments in arithmetic and geometry seem not to hinder students of varying ability. Inclusion of figural material may help students high in figural ability. But the specific conditions under which this occurs remain uncertain.

Traditional Math vs. New Math

Traditional math instruction can be characterized as textbook with drill and practice in computation and word problems. New math takes a more conceptual approach presenting the rationale underlying the computations and problems, emphasizing graphs and pictures in presenting mathematical concepts. Table 6 summarizes studies bearing on ATIs with traditional and new math.

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Insert Table 6 here

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The studies summarized in Table 6 suggest that new math is more beneficial for students who are high in figural ability, visualization and crystalized abilities than those low in these abilities when computational outcomes are examined. Traditional math seems to be more beneficial for students high on verbal abilities. When other outcomes such as attitudes or comprehension are used, too few studies are reported to draw conclusions. The general pattern with respect to computational outcomes, then, is that the more structured drill and practice of traditional math programs is more dpendent on verbal and comprehension abilities, while the more flexible, conceptual approach of new math programs is more dependent on spatial and figural abilities.

Summary and Recommendations

(1) The findings on logical vs. random sequencing of frames in programmed instruction suggest the following match between students' aptitudes (general mental ability) and the treatments:

(a) For students low in ability, provide a logical sequence of frames in programmed instruction;

(b) For students high in ability, provide a scrambled sequence of frames (!).

(2) The findings on the effect of linear vs. branching programs for students varying in academic and general ability are equivocal.

(3) The findings on the effect of linear vs. branching programs and self-direct vs. program-direct study on students varying in general mental ability are equivocal. A very tentative conclusion is that students of high ability may profit more from branching programs and self direction. Due to the tentativeness of this finding, a decision rule cannot be recommended.

(4) The findings on the effect of overt and covert responding to programmed instruction (PI) frames on students of varying general mental ability lead to the following match:

(a) For students low in ability, use PI with covert responding;

(b) For students high in ability, use PI with overt responding.

Note, however, that this recommendation is based on three studies.

(5) The findings on the effect of programmed (PI) vs.

conventional instruction (CI) on students of varying general mental ability are equivocal as are the findings on the effect of PI vs. CI for students varying in crystallized.

(6) The findings on the effect of deductive vs. inductive sequences of instruction on students varying in crystallized and general mental ability suggest the following match of students to treatments:

(a) For low ability students, provide a deductive sequence of instruction.

(b) For high ability students, provide either an inductive or deductive sequence of instruction.

(7) The findings on the effect of mastery vs. conventional instruction on students of varying abilities are equivocal.

(8) The findings of the effect of verbal vs. nonverbal instruction suggest the following:

(a) Regardless of ability, assign to verbal treatments.

(b) For high (figural) ability students, figural content added to verbal material may prove helpful.

(9) The findings on the effect of conventional math (drill and practice) and new math (conceptual approach) suggest the latter benefits students high in figural and crystallized abilities, while the former benefits students high in verbal ability. There are too few studies to permit a recommendation on the basis of these studies alone. However, including the Greeno studies here (Egan & Mayer, 1973; Mayer & Greeno, 1972), the following recommendations can be

made:

(a) The type of instructional treatment has a direct effect on what is learned. In general, drill and practice improve computational ability while conceptual treatments affect scores on conceptual problems (see also Walker & Schaffarzick, 1974).

(b) For students high in figural and analytical ability, provide conceptual instruction.

(c) For students high in verbal ability, provide drill and practice on those types of problems they are expected to learn, including conceptual problems.

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Footnotes

2. Aptitude refers to any characteristic of the student that increases his or her chances of success with a particular instructional method.

Table 1

Summary of the ATI Studies Comparing Different Methods and Sequences of Programmed Instruction in Quantitative Subject Matters

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
I. Logical vs. Scrambled Sequences			
Crystallized ability	Payne et al. (1967)	Statistical concepts; college; N = 238; ATI trend.	Low ability students performed better in a completely scrambled sequence; high ability students performed better in a completely smooth sequence. However, there was unsystematic variability between the slopes for the other treatments.
	Pyatte (1969)	Measurement; elementary N = 156; ATI present.	Low ability students performed better with scrambled sequence instruction, better with logical sequence.

Table 1 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General mental ability	Brown (1970)	Number series; high school; N = 37; ATI trend.	High ability students performed better than low ability students in the scrambled sequence; no difference in the logical sequence.
	Buckland (1968)	Number base; junior high; N = 78; ATI present.	Same general findings as Brown.
	Cartwright (1962)	Fractions; educationally mentally retarded; N = 36; ATI trend.	No significant differences on any outcome measure. Correlations of GMA and posttest scores were .187 and .614 in the smooth and scrambled groups respectively. Correlations of math aptitude and posttest were .738 and .414 in the smooth and scrambled treatments, respectively (!).

Table 1 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General mental ability (cont.)	Levin & Baker (1963)	Geometry; elementary; N = 36; ATI trend.	High ability students performed better than low ability students with scrambled sequence.
	Spencer & Briggs (1972)	Equations; level not reported; N = 175; ATI present.	High ability students performed better than low ability students in the scrambled sequence; no difference in the logical sequence.
	Stolurow (1964)	Fractions; educational mentally retarded; N not reported; ATI present.	Low ability students performed better in the smooth sequences while the high ability students performed well, regardless of sequence.
	Traub (1964)	Addition; elementary; N = 294; no ATI.	Main effect favored heterogeneous problem sets.

Table 1 (cont.)

	Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
II.	Linear vs. Branching Programs			
	Crystallized ability and general mental ability	Beane (1965)	Geometry; high school; N = 48; no ATI.	No main effects or ATIs.
		Hartley (1965)	Trigonometry; high school N = 68; ATI present.	High IQ girls (females only) benefitted from the branching program; low IQ girls performed about the same on the two treatments.
		Senter et al. (1964)	Computer arithmetic; college; N = 60; no ATI.	No main effects or ATIs.
III.	Self-pacing vs. Program-pacing			
	Crystallized ability	Campbell (1964)	Set theory; junior high; N not reported; ATI trend.	Self-pacing benefitted highs while program pacing benefitted lows. However, with training in self-pacing, this treatment proved suprior to program pacing

Table 1 (Cont.)

	Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
	Crystallized ability (cont.)	Judd et al. (1970)	Trigonometry; college; N = 147; no ATI.	Insufficient data to test the interaction of aptitude and treatments.
IV.	Overt vs. Covert Responding			
	Crystallized ability	Buckland (1967)	Number bases; high school; N = 47; ATI present.	Low ability students benefitted most from covert responding while high ability students benefitted most from overt responding.
		Entweistle et al. (1968)	Operator graph; college; N = 44, 48; ATI present. present.	Findings similar to Buckland's.
	General mental ability	Lambert et al. (1962)	Sets; junior high; N = 552; ATI trend.	Covert may benefit low and middle ability students while overt may benefit high ability students.

Note: ATI present means statistically significant ATI; ATI trend means descriptive statistics indicate ATI--power too low for inference test to be meaningful; and no ATI means no indication of ATI.

Table 2

Summary of the ATI Studies Comparing Programmed Instruction (PI) and Conventional Instruction (CI) in Quantitative Subject Matters

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability	Fisher (1973)	Geometry; High school; N not reported; ATI present.	PI more effective for low and middle ability; CI more effective for high ability students.
	Goodson (1975)	Linear equations; college; N = 93; no ATI on achievement; ATI present on time.	No difference between PI and CI on achievement; students high in achievement spent less time studying PI while no difference in time studying PI and CI was found for low achievers.
	Miller (1964)	Fractions; elementary; N = 114; no ATI.	PI superior to CI regardless of ability level.

Table 2 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability (cont.)	Ott (1976)	Physics; high school; N not reported; no ATI.	CI was revised to have characteristics similar to PI; no differences found.
	Ott & Macklin (1975)	Physics; college; N = 303; ATI present.	CI better for high ability students; PI better for low ability students.
	Willis & Wicks (1964)	Trigonometry; high school	CI tended to minimize difference between lows and highs; PI superior for highs.
General mental ability	Cavanagh et al. (1965)	Measurement; adults; N = 158; ATI present.	CI tended to minimize difference between lows and highs; PI superior for high ability students.
	Knight (1964)	Trignometry; college; N = 59; ATI present.	Highs benefitted more from CI while lows benefitted more from PI.

Table 2 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General mental ability (cont.)	Tuckman & Orefice (1973)	Accounting; college; N = 120; ATI present.	CI and independent study benefitted highs (abstract ability) while PI was systematically low for all.

Note: ATI present means statistically significant ATI; ATI trend means descriptive statistics indicate ATI--power too low for inference test to be meaningful; and no ATI means no indication of ATI.

Table 3

Summary of the ATI Studies Comparing Deductive and Inductive Sequences of Instruction in Quantitative Subject Matters

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability	Anastasiow et al. (1970)	Pre-number ideas; kinde N = 36; ATI present.	Lack of power makes results inconclusive (pretest and picture vocabulary tests used).
	Catanyano & Godwin (1977)	Modules arithmetic; college N = 27; ATI trend.	Inductive sequence more effective for highs, deductive sequence more effective for lows.
	Egan & Greeno (1973)	Binomial theorem; college N = 72; ATI present.	For low ability (pretest and IQ), deductive led to better performance than inductive; for medium and high ability, no difference between treatments was found.

Table 3 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability (cont.)	Mayer & Greeno (1972)	Binomial theorem; college; N = 44; ATI present.	Highs performed better than lows in a treatment emphasizing meanings of concepts while lows performed better than highs in a treatment emphasizing algorithms.
	Mayer et al. (1975)	Binomial theorem and Bayes' theorem; college; N = 44 in Study 1; N = 90 in Study 2; ATI present.	Study 1: Low ability perform best in the deductive (algorithm) treatment while high ability perform best in the inductive group. Study 2: Students with no prior familiarity perform best in deductive treatment while students with some familiarity perform equally well in either treatment.

Table 3 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General mental ability	Becker (1967)	Number series; high school; N = 68; no ATI.	No main effect or ATI.
	Brown (1963)	Elementary mathematics; elementary; N = 2,600.	Data problems (see Cronbach & Snow, 1977, p. 298).
	Maynard & Strickland (1969)	General mathematics; high school; N = 400; ATI present.	Lecture or guided discovery, in contrast to self-discovery, benefitted highs; no important difference was found between sequences for lows (they did poorly).
	Nelson & Frayer (1972)	Geometry; junior high; N = 228; no ATI.	Deductive sequence best for all.

Table 3 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General mental ability (cont.)	Rector & Henderson (1970)	Probability; college; N = 182; no ATI.	Deductive sequence best for all on low level concepts; added examples aided lows on higher level concepts.
	Sobel (1956)	Algebra; high school; N = 40 classes; ATI present.	Inductive sequence more effective for highs; no difference between sequences for lows.
Personality	Branch (1973; Note 3)	Addition and subtraction; elementary; N = 72; ATI present.	Students low in analytic style (cf. Siegel) benefitted from an inductive treatment; no treatment difference for high analytic students.
	Trown (1970)	Algebra; high school; N = 128; ATI present.	Introverts benefitted from deductive sequence; extroverts benefitted from inductive sequence.

Note: ATI present means statistically significant ATI; ATI trend means descriptive statistics indicate ATI--power too low for inference test to be meaningful; and no ATI means no indication of ATI.

Table 4

Summary of ATI Studies Comparing Mastery and Conventional Instruction

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability	Block (1970; Note 4)	Matrix algebra; college; N ∿ 100.	An ATI judgment cannot be made from the data (see, for example, Cronbach & Snow, 1977, p. 139).
	Burrows (1973)	Geometry; elementary; N = 84; no ATI.	Main effect favoring mastery.
	Pascarella (1977; 1978)	Calculus; college; N = 94, 248; ATI present.	Low ability students performed better in a master treatment while high ability students performed well in either treatment.
	Smith (1962)	Statistics; college; N = 128; no ATI.	No main effects or ATI.
General mental ability	Yeager (1969)	Arithmetic; elementary; N = 404.	Sampling problems make an ATI judgment hazardous.

Note: ATI present means statistically signficant ATI; no ATI means no indication of ATI.

Table 5

Summary of the ATI Studies Comparing Verbal, Nonverbal and Other Instructional Treatments in Quantitative Subject Matters Developed to Capitalize on Particular Aptitudes

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Crystallized ability	Montgomery (1973)	Geometry; elementary; N = 54; ATI trend.	Main effect for method requiring restructuring of graph information. Restructuring slightly better for lows on transfer test than congruent treatment.
General mental ability	Hancock (1975)	Linear order relations; high school; N = 170; ATI trend.	No main effect. For subjects high in figural ability, the figural treatment was superior to the verbal treatment. For subjects high in verbal ability, the verbal treatment was superior.
	James & Knief (1978)	Mathematical concepts; elementary; N = 180; ATI present	For lows, instruction focused on fluid ability was most beneficial. For highs, instruction focused on crystallized ability was most beneficial.

Table 5 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Verbal and nonverbal ability	Behr (1967)	Modules arithmetic; college; N = 228; ATI present.	Highs on nonverbal (figural) benefitted from the figural treatment; no difference between lows and highs in the verbal treatment.
	Kropp (1967)	Set concepts; elementary; N = 426; no ATI.	No ATI with verbal and figural treatments; negligable main effects.
	Peterson & Hancock (1974; Note 5)	Network tracing; college; N = 170; ATI trend.	Smallest difference between students low and high on verbal ability was in the verbal instruction treatments; steeper regression slopes in the figural and symbolic treatments. (Methodological problems.)
	Sederberg (1966)	Algebra; junior high school; N = 222; no ATI.	No main effect for treatment or ATI.

Table 5 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General ability and visualization ability	Carry (1968)	Quadratic inequalities; high school; N = 181; ATI present.	Students low on reasoning ability and high on visualization did better in an analytic treatment while students high on reasoning and low on visualization did better in a graphical treatment.
	Eastman & Carry (1972)	Quadratic inequalities; high school; N = 80; ATI present.	Exactly the opposite results of Carry (1968).
	Webb & Carry (1971)	Quadratic inequalities; high school; N = 249; no ATI.	No ATIs as found by Carry (1968) or Eastman & Carry (1972).

Table 5 (Cont.)

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
General ability and visualization ability (cont.)	Young (1978)	Quadratic inequalities; high school; N = 61; ATI present.	High figurals benefitted more from a figural followed by a symbolic sequence while low figurals benefitted more from a symbolic to figural sequence.

Note: ATI present means statistically significant ATI; ATI trend means descriptive statistics indicate ATI--power too low for inference test to be meaningful; and no ATI means no indication of ATI.

Table 6

Summary of the ATI Studies Comparing Traditional Math (TM) and New Math (NM) in Mathematics Instruction

Aptitude	Study	Subject matter; level of education; N; presence of ATI	Major findings
Spatial ability and verbal ability	Osburn & Melton (1963)	Algebra; high school; N = 155; ATI present.	NM more dependent on spatial ability than old math. Old math more dependent on verbal abilty than NM.
Visualization ability	NLSMA[a] (1972)	Mathematics; elementary through high school; N = 112,000; ATI present.	For boys, NM is beneficial for highs in computation but not for lows. NM advantageous for lows in improving comprehension but less so for highs. The reverse was found for girls.
Crystallized ability	Sabers (1967)	Algebra; high school; N = 1,000; ATI present.	Ability was more strongly related to outcomes in NM than TM.
	Wasik (1971)	Physics; high school; N - 728; ATI present.	PSSC physics (cf. NM) benefitted students high in mathematical ability and hindered students low in this ability.

Table 6 (Cont.)

Aptitude	Study	Subject matter; level of education; presence of ATI	Major findings
Personality; attitude toward math	Ryan (1968)	Algebra; junior high; N = 126; ATI present.	Girls' attitudes toward math were less related to outcomes in one NM curriculum than two others or TM.

Note: ATI present means statistically significant ATI.

[a]NLSMA, the National Longitudinal Study of Mathematical Ability, contains evidence of many potential ATIs with new math and conventional math. Only one explame finding, reviewed by Cronbach and Snow (1976) is reviewed here.